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AUSTRALIA

PATENTS ACT 1990

PROVISIONAL SPECIFICATION

FOR THE INVENTION ENTITLED:-

"A RADIO FREQUENCY IDENTIFICATION ("RFID") DEVICE"

The invention is described in the following statement:-

A RADIO FREQUENCY IDENTIFICATION ("RFID") DEVICE

FIELD OF INVENTION

The present invention relates to a radio frequency identification ("RFID") device.

The invention has been developed primarily as a radio frequency identification ("RFID") tag for a document or postal handling system and will be described hereinafter with reference to these applications. However, the invention is not limited to those particular fields of use and is also suitable to inventory management and other stock control systems.

BACKGROUND

Passive RFID tags are known and generally include a resonant tuned antenna coil that is mounted to a substrate and electrically connected to an integrated circuit (IC). Examples of RFID tags that include a resonant tuned antenna coil are US 5,517,194 (Carroll et al), US 4,546,241 (Walton), US 5,550,536 (Flaxel) and US 5,153,583 (Murdoch). These systems have been developed for applications such as baggage handling.

The tuned antenna coil has a resonant frequency, and it is at that frequency that an interrogator generates a magnetic field. When the coil is located within the field, the two couple and a voltage is generated in the coil. This voltage is magnified by the coil's Q factor and is used to provide electrical power to the IC. This power is used by the passive tag to allow the generation of a coded identification signal that is transmitted to the interrogator.

The resonant current that flows in the tuned antenna coil also generates a magnetic field in the region of the coil. This is not usually problematic, unless there is an object – such as another tag – disposed near the coil that couples with the magnetic field. Should that coupling occur, the voltage generated by the coil will be reduced. This, in turn, will reduce the power that is available for use by the tag. If insufficient power is available, the tag will not function in that it will not provide the identification signal to the interrogator.

In applying RFID tags to baggage handling systems the coupling referred to above is not overly problematic as the separate tags are usually spaced sufficiently apart to allow reliable operation. However, this does place limitations upon the density of baggage that is able to be effectively handled and can create bottlenecks at the interrogation step. It also limits that application of such tags to other fields.

The discussion of the prior art within this specification is to assist the addressee understand the invention and is not an admission of the extent of the common general knowledge in the field of the invention.

SUMMARY OF THE INVENTION

It is an object of the present invention to overcome, or at least substantially ameliorate, one or more of the disadvantages of the prior art or at least to provide a useful alternative.

According to a first aspect of the invention there is provided a radio frequency identification ("RFID") device, the device including:

an antenna for receiving an interrogation signal; and

a transceiver connected to the antenna and being responsive to the interrogation signal, whereby the transceiver selectively draws current from the antenna.

Preferably, the transceiver toggles between a first mode and a second mode, wherein the current drawn by the transceiver during the first mode is greater than the current drawn during the second mode. More preferably, the transceiver selects the second mode more frequently than the first mode. Even more preferable, the probability of selecting the second mode is at least twice the probability of selecting the first mode.

In the preferred embodiments, the transceiver has an operating cycle with a start and a finish wherein, during that cycle, the transceiver is in either the first or the second mode. Preferably also, the transceiver selects the first mode with a small probability of less than 1/2. More preferably, the probability is less than 1/4. Even more preferably, the probability is less than or equal to 1/16. That is, the first mode is not necessarily selected in each cycle. In use, the interrogation signal is generated in a predetermined field by an interrogator, wherein device is maintained within the field for more than one cycle. More preferably, the device is maintained within the field for at least that number of cycles that is the reciprocal of the probability of the first mode being selected.

In a preferred form, the selection of the first mode and the second mode is based upon a predetermined algorithm. An example of a preferred algorithm is a random or a pseudo-random number used to determine the mode selection of the transceiver in a cycle.

Preferably, the antenna and the transceiver are mounted to a common substrate. More preferably, the antenna is a coil and the current is generated in the coil in response to the interrogating signal.

Preferably also, during the first mode, the current drawn by the transceiver is to allow its operation. That is, the first mode is a normal mode, while the second mode is a standby mode. For example, in the normal mode the current supplies the relevant clock circuits, the signal processing circuit, and the like. In this mode the current also allows the transceiver to generate an identification signal. More preferably, the transceiver relies upon the current to drive the antenna to transmit the identification signal. In other embodiments the device includes a separate transmission antenna and the transceiver drives that separate antenna to transmit the identification signal. In both cases, the current drawn from the antenna is the source of power for the generation and transmission of the identification signal. That is, the device is passive in that it does not have an onboard power source. Clearly, the invention is also applicable to active devices to prolong the life of the onboard power source being used.

According to a second aspect of the invention there is provided a radio frequency identification ("RFID") device, the device including:

an antenna for receiving an interrogation signal and being responsive to the signal for supporting an antenna current;

a coupling connected to the antenna for toggling the antenna current between a first mode and a second mode, wherein the antenna current in the first mode is greater than the antenna current in the second mode; and

a transceiver connected to the coupling and drawing an operational current that is derived from the antenna current, whereby the transceiver is selectively responsive to the interrogation signal to generate an identification signal.

Preferably, during the first mode the transceiver is responsive to the interrogation signal to generate the identification signal. More preferably, in the second mode the device is responsive to the interrogation signal only for the purpose of toggling the antenna current between the first and second modes. That is, the first mode is a normal current mode, whereas the second mode is a low current or standby mode.

Preferably also, the antenna is responsive to the transceiver for transmitting the identification signal. In other embodiments, however, the device includes a separate antenna that is responsive to the transceiver for transmitting the identification signal.

According to a third aspect of the invention there is provided a system for identifying articles that are collocated with an RFID tag of the first aspect, the system including:

an interrogator for providing an interrogating field;

a plurality of identification devices mounted to the respective articles, the devices including: respective antennas for being contemporaneously disposed within the field and being responsive to that field for providing antenna currents; respective transceivers that are connected to the antennas for selectively toggling the currents between an operational mode and a standby mode such that not all the currents are simultaneously in the operational mode, whereby the transceivers are responsive to the currents for providing identification signals that include identification data unique to the respective articles; and

a receiver for processing the identification signals to extract the identification data and thereby identify the respective articles.

Preferably, the current drawn by the transceiver during the operational mode is greater than the current drawn during the standby mode. More preferably, the transceiver selects the standby mode more frequently than the operational mode. Even more preferable, the probability of selecting the second mode is at least twice the probability of selecting the first mode.

In the preferred embodiments, the transceiver has an operating cycle with a start and a finish wherein, during that cycle, the transceiver is in either the first or the second mode. Preferably also, the transceiver selects the first mode with a small probability of less than 1/2. More preferably, the probability is less than 1/4. Even more preferably, the probability is less than or equal to 1/16.

In a preferred form, the selection of mode is based upon a predetermined algorithm. An example of a preferred algorithm is a random or a pseudo-random number used to determine the mode selection of the transceiver.

Preferably, the identification signals are transmitted while the respective transceivers are in the first mode. More preferably, the transceivers use the respective antennas to transmit the identification signals. In other embodiments, however, the devices include respective second antennas that are used by the transceivers to transmit the identification signals.

According to a fourth aspect of the invention there is provided a radio frequency identification ("RFID") device including:

an antenna that is responsive to an interrogation signal for providing an antenna current; and

a transceiver for selecting between a normal mode and a standby mode wherein, during the normal mode, the transceiver is responsive to the interrogation signal for generating an identification signal and, during the standby mode, the transceiver is only responsive to the interrogation signal for selecting between the normal and standby modes.

Preferably, in the absence of the interrogation signal the device is inactive. Conversely, in the presence of an interrogation signal, the device is either in the normal mode or the standby mode. However, the normal mode has a short duration and, typically, when the device is in the presence of an interrogating signal, it will be predominantly in the standby mode. Preferably, during the standby mode, the device is only responsive to the interrogation signal for the purpose of selecting between normal and standby modes.

According to an fifth aspect of the invention there is provided a voltage regulator for a radio frequency identification ("RFID") device having an antenna for receiving an interrogation signal and for transmitting an identification signal and a transceiver for being responsive to the interrogation signal to generate the identification signal, the regulator including:

a data coupling for linking the antenna and the transceiver and which selects between a first mode and a second mode wherein, in the first mode, the coupling draws a first current from the antenna and is responsive to the identification signal and, in the second mode, the coupling draws a second current from the antenna that is less than the first current; and

a current coupling for providing a supply voltage to the transceiver, the current coupling, in the first mode, drawing a third current from the antenna and, in the second mode, drawings fourth current from the antenna that is less than the third current.

BRIEF DESCRIPTION OF THE DRAWINGS

Preferred embodiments of the invention will now be described, by way of example only, with reference to the accompanying drawings, in which:

Figure 1 is a schematic circuit diagram of a typical prior art tag;

Figure 2 is a schematic circuit diagram of an RFID device according to one embodiment of the invention;

Figure 3 is a schematic circuit diagram of another embodiment of the invention that includes a voltage multiplier;

Figure 4 is a schematic circuit diagram of a further embodiment of the invention that includes a voltage doubler circuit;

Figure 5 is a schematic circuit diagram of a further embodiment of the invention that includes both a voltage doubler circuit and a full wave circuit;

Figures 6 is a schematic circuit diagram of a further alternative embodiment of the invention that includes a circuit for changing the current collection efficiency of the antenna;

Figure 7 is a schematic circuit diagram of a further embodiment of the invention where the circuit for changing the current collection efficiency is on the DC side;

Figure 8 is a schematic circuit diagram of another embodiment of the invention that includes a circuit for changing the operating voltage;

Figure 9 is a schematic circuit diagram of a further embodiment of the invention that includes a series voltage regulator circuit;

Figure 10 is a circuit model for the prior art circuit of Figure 1;

Figure 11 is a circuit model for the device of Figure 2;

Figure 12 is a perspective view of a plurality of stacked envelopes each of which contains a device according to Figure 2;

Figure 13 is a plan view of an RFID device including the circuit of Figure 2;

Figure 14 is a perspective cut-away view of a parcel according to another aspect of the invention;

Figure 15 is an alternative embodiment to that of Figure 2, where the antenna coil is substituted with a generic interrogation signal receiving device;

Figure 16 is an alternative embodiment to that of Figure 15; and

Figure 17 is a further alternative embodiment to that of Figure 15.

DETAILED DESCRIPTION

Referring particularly to Figure 2 and Figure 13, there is illustrated a first embodiment of the invention in the form of a radio frequency identification ("RFID") device or tag 1. The tag includes an antenna in the form of a generally rectangular multi-turn coil 3 for receiving an interrogation signal. A transceiver, in the form of an integrated circuit (IC) 4, is connected to coil 3 and is responsive to the

interrogation signal. Coil 3 and the circuit 4 are in this embodiment mounted on a common generally rectangular substrate 2. As will be better appreciated from the following disclosure, circuit 4 selectively draws current from coil 3 when that coil is in the presence of an interrogation signal.

Circuit 4 toggles between a first mode and a second mode, wherein the current drawn from coil 3 by circuit 4 during the first mode is greater than the current drawn during the second mode. In this embodiment, the selection of the second mode by circuit 4 is about 16 times more probable than the first mode. That is, the probability of circuit 4 drawing a high current – and thereby being at risk of mutually coupling tag 1 with an adjacent tag – is 1/16.

Circuit 4 has a current cycle and during that cycle the circuit randomly selects either the first or the second mode for the duration of the cycle. The random selection of mode during a cycle by each individual tag reduces the risk of two adjacent tags simultaneously operating in the first mode. This allows the tags to continue to operate at a much smaller spatial separation than could be achieved by the prior art tags.

The selection of mode is made using a predetermined algorithm. An example of a preferred algorithm is a random or a pseudo-random number algorithm.

In the preferred embodiment coil 3 is used to transmit an identification signal generated by the transceiver. In other embodiments, however, a second separate antenna coil is used to transmit the identification signal.

Substrate 2 is about 80 mm by 50 mm and includes a plurality of layers that are laminated together to encapsulate coil 3 and circuit 4. The thickness of tag 1 is about 0.3 mm. In other embodiments the dimensions of tag 1 are different. However, for the described embodiments the preferred form the thickness is small to facilitate the unobtrusive incorporation of the tag into packaging and other articles.

While in this embodiment the antenna is a coil 3, in other embodiment use is made of other devices for receiving the interrogation signal. Examples of such alternative devices for receiving the interrogation signal are shown in Figures 15, 16 and 17. Figure 15 shows the circuit of Figure 2 where the interrogation signal is received by a non-specific or generic receiving device 31. The receiving device is, as shown in the figure 2 embodiment, an antenna coil 3 for receiving a magnetic or inductive interrogation signals. However, in other embodiments, such as that of Figure 16, device 31 includes a dipole 32 for receiving a radiated interrogation signal. In other embodiments (not shown) device 31 is a monopole. In still further embodiments, such as that illustrated in Figure 17, device 31 includes a capacitive antenna 33 for receiving an electric, or capacitive, interrogation signal. It will be understood by the skilled addressee, from the teaching herein, that the invention is applicable to all of these circuits and is not limited by the choice of antenna or the specific form of interrogation signal.

Before further describing the embodiments of the invention, it is beneficial to examine the operation of a typical prior art tag. Such a tag includes a circuit 5 that is illustrated schematically in Figure 1. Particularly, a tag antenna coil L1 is tuned by the tuning capacitor C1. A voltage V1 is induced in the coil by the interrogation field. L1 and C1 form a resonant tuned circuit, which magnifies the voltage V1 by the loaded Q factor of the antenna coil. The AC voltage that is generated across the tuned circuit is rectified by a rectifier 6 and the DC output voltage is stored on a storage capacitor C2. The DC load of the IC is represented by R1.

Figure 10 shows a circuit model for the prior art circuit 5 where corresponding features are denoted by corresponding notations. The antenna coil is represented by inductance L1 and the coil losses by series resistance R5. The tuning capacitance and circuit stray capacitance is represented by C1 and the losses of the rectifier and IC circuit by R3. The resonant currents circulating in the tuned circuit formed by L1 and C1 are I1 and the output current into R3 is I2. The capacitor Q factor ($Q_c = w.R3.C1$) normally dominates the total resonant Q factor. Typically, Qc has a value of between 10 and 40. Under these conditions the ratio of $I1/I2 = Q$ and the resonant current is much larger than the output current. When tags of this type are in close proximity the field generated by the resonant current couples through the mutual inductance into the proximate tags and subtracts from V1. Typically, once the tags are in close proximity, that is within about 50 mm of each other the interference sufficiently compromises the operation of the tags to make them impractical.

It has been appreciated by the inventors that for tags operating in close proximity to each other it is important that these resonant currents are eliminated. Given this, the ideal scenario for tags that are operating in close proximity is to ensure there is no resonant capacitor connected to the antenna coil. It has been found by the inventors that by disconnecting the resonant capacitor from the antenna coil it is possible to eliminate these resonant currents. However, even with the resonant capacitor removed from the prior art devices, the antenna current drawn by circuit 5 is still too large to allow a plurality of like tags to be closely stacked. If the tags are within a few millimetres of each other the currents drawn by the respective circuits 5 from their antenna coils will, in effect, stop the tags operating with the required reliability.

In the embodiments of the invention described in this specification, the tags exist in at least two states: a normal current state where the IC draws the normal operating current from the antenna coil; and a low current state where the IC draws the smallest current possible from the antenna coil.

Returning to Figure 2 and Figure 12, in the normal current state tag 1 is fully functional as circuit 4 is fully powered by the current from the antenna coil. Advantageously, this current is minimised as part of good design.

In the low current state tag 1 is not fully functional. When tag 1 is not fully functional the current is reduced to the smallest possible value and the current drawn is only sufficient to maintain the barest of circuit functions needed for correct operation. In this embodiment, the current is in the order of 30 μA.

Ideally, the current is zero, and in other embodiments this ideal is more closely realised by one or more of a variety of methodologies including:

1. Minimising the required functions to be performed by the circuitry
2. Utilising low power circuitry
3. The use of onboard energy storage devices and in particular a capacitive device.

When the antenna coil current becomes very small or, as in some cases zero, the coil becomes transparent to the interrogation field. In this state the antenna coil has no effect upon the interrogation field and those tags in the low current state do not interfere with the operation of those tags in the normal current state.

More generally, the impedance seen by the antenna coil should be as large as possible and particularly so in the low current state. Any currents drawn from the antenna coils will generate a magnetic field that will oppose the interrogation field. The current drawn from the antenna is due to a number of possible factors, such as the load defined by circuit 4, a tuning capacitor or stray capacitance. That is, the quantum of the current is responsive to the quantum of the resistive and/or the reactive load as seen by the coil. This current will reduce the voltage induced by the interrogator in all proximate tag coils. When there is sufficient coil current and coil-to-coil coupling the tags will stop operating.

In the Figure 2 embodiment, circuit 4 does not include a resonating capacitor. The voltage V1 is induced in the antenna coil L1 by the interrogation field. The antenna voltage is rectified and stored on a DC storage capacitor C2. Resistors R1 and R2 are representative of the load provided by circuit 4 in the low current state and the normal current state respectively. The switch SW1 is representative of the reduction in current drawn by circuit 4 when in low current mode. With the benefit of the teaching herein, it will be appreciated by those skilled in the art that one of the many well known methods for disabling circuits and reducing their current consumption are applicable to achieve the functionality required. For example, the hardware and software method for putting a microprocessor into a "standby" or a "sleep" mode.

In the low current state the quiescent current Iq is drawn. The current Iq is very small and is typically a few tens of microamperes. In this embodiment, Iq represents the current used to: maintain RAM data stored in CMOS memory, operate logic functions; and power analogue circuitry.

In Figure 2 the low current state is represented by switch SW1 being open and the current Iq being drawn through R2.

In the normal current state an additional current Ic is drawn. The current Ic is representative of the additional current drawn by circuit 4 when in the normal current state. The total current drawn by circuit 4 in the normal current state is (Iq + Ic) and is typically about 300 uA, although this does vary considerably between embodiments. In the Figure 2 embodiment, the normal current state is represented by SW1 being closed and indicates the connection or activation of all the functionality of circuit 4.

The change in the current drawn by circuit 4 in the low current and the normal current state is reflected in a corresponding change in the current in the antenna coil. In the low current state the antenna current is likewise tens of microamperes and in the normal current state the antenna current is hundreds of microamperes.

Figure 11 illustrates a circuit model for tag 1. Particularly, the voltage V1 is induced in the antenna coil L1 by the interrogation field. Resistor R5 represents the series resistance of the antenna coil and R4 represents the equivalent AC resistance of circuit 4. Current I2 flows from the antenna coil into R4. The voltage V4 across R4 represents the voltage at the antenna terminals of L1 and circuit 4. . The antenna voltage V4 is rectified and stored on a DC storage capacitor C2 as shown in Figure 2. V4 equals V1 minus the volt drop in L1 and R5 due to the current I2 flowing through L1 and R5. That is:

$$V4 = V1 - I2.(R5 + jwL1)$$

where jw is the complex frequency in radians per second. This equation can be rearranged into the following two forms.

$$I2 = (V1 - V4)/(R5 + jwL1)$$

and

$$I2 = V1/(R4 + R5 + jwL1)$$

Assuming that the voltage V1 and the inductance L1 is fixed, then the current I2 is adjusted by varying either V4, R4 or R5. In this embodiment:

1. I2 is varied by changing V4. That is, by increasing the output voltage more voltage appears at the coil terminals and less current is drawn from the antenna coil;
2. I2 is varied by changing R4. That is, by increasing the AC resistance of the circuit 4 less current is drawn from the antenna coil; and
3. I2 is varied by changing R5. That is, by inserting an extra resistance in series with R5, increasing R5 then a larger voltage is dropped in the antenna coil impedance and less current is drawn from the antenna coil.

These embodiments are shown in Figures 4, 5, 6, 7, 8 and 9 and will be described in the following text. It will be appreciated by the skilled addressee that elements of these various embodiments are able to be combined to provide alternate adjustment of I2.

Another embodiment of the invention is shown in Figure 3, where corresponding features are denoted by corresponding reference terms. In this case, an integrated circuit 7 includes, rather than a rectifier, a voltage multiplier circuit 8. This is advantageous since the absence of resonant tuning results in the voltage at the coil terminals being low. That is, the voltage is not magnified by the Q multiplication. To compensate, circuit 8 increases the voltage supplied to circuit 7 and allows the circuit to operate with a lower coil voltage. A lower coil voltage corresponds to a lower interrogation field strength.

A further embodiment of the invention is illustrated in Figure 4, where corresponding features are denoted by corresponding reference terms. In this embodiment, there is provided an integrated circuit 9 where the rectifier is a voltage doubler circuit 10. In other embodiments use is made of other types of voltage multipliers such as triplers or quadruplers. In this embodiment the implementation of such a voltage multiplier circuit is achieved via standard IC processes and would be understood by those skilled in the art.

Voltage multipliers are advantageous because the voltage induced in the coil is not magnified by a tuning capacitor. The impedance level of the coil used in the preferred embodiments is low – in the order of 200 ohms – and thereby ideally suited to being connected to a voltage multiplier.

Figure 5 shows a further embodiment of the invention where the rectifier circuit changes its configuration between that of a voltage doubling rectifier or a full wave rectifier. A switch, in the form of a MOSFET transistor T1, is used to select either the normal current state or the low current state. When transistor T1 is closed and open the circuit respectively acts as a voltage doubler and a full wave rectifier. The voltage doubler has a voltage gain of two and transforms the load impedance of the chip to R4 by a factor of 8. The full wave rectifier has a voltage gain of one and transforms the load impedance by a factor of 2. Compared to the full wave circuit, the voltage doubler circuit draws a significantly larger current from the antenna coil and is the normal current state rectifier. Accordingly, the full wave rectifier is switched in during the low current state. The drive for transistor T1 is provided by the transceiver.

The embodiment of Figure 6 shows a circuit 11 that includes a sub-circuit 12 for changing the current collection efficiency of the antenna by inserting an extra resistance R3 in series with the antenna coil L1 when circuit 11 is in the low current state. The extra resistance drops voltage across itself and reduces I2. Both of these effects reduce the current collection efficiency and antenna coil current. This is advantageous for reducing the current drawn from the antenna during the low current state. In other embodiments, such as that shown in Figure 7, circuit 12 is placed on the DC side of the rectifier.

The embodiment shown in Figure 8 includes a circuit 15 that utilises a shunt regulator 16 for controlling the operating voltage provided to the integrated circuit. A detailed explanation of the operation of the shunt circuit is given in US 5,045,770. The operating voltage is changed such that the low current state operating voltage VA + VB is higher than the normal current state operating voltage VB. At a higher operating voltage less current is drawn from the antenna to maintain the operating voltage. Hence, in the low current state, less current is drawn from the antenna. The low current state operating voltage is set as high as is possible given the limitations of the IC technology. In this embodiment, for example, VA + VB = 4.2 volts and VB = 2.1 volts.

The embodiment of Figure 9 includes a circuit that utilises a series regulator for controlling the operating voltage. The input voltage to the regulator increases when the circuit toggles into the low current state.

Figure 12 illustrates an application of an embodiment of the invention. Specifically, 100 small envelopes are placed in a horizontal stack in a cardboard box. Each envelope is used to store a jewel or gem and a report on the characteristics of the jewel. To maintain an accurate perpetual stock inventory each jewel must be regularly accounted for. Previously, this process has been achieved manually and is both time consuming and prone to error. In this embodiment, however, a plurality of RFID tags 1, which are capable of being stacked, are placed in respective envelopes and are within a few millimetres of at least one adjacent tag. Each tag 1 is programmed with the jewel's characteristics such that when interrogated the uniquely coded identification signal will provide the interrogator with a data that is indicative not only of the identity of each tag in the box, but also of the jewels contained within the envelopes. Accordingly, the whole box of jewels is accounted for in one automatic process. For example, in one embodiment, an interrogator is placed at a passage through which the box is passed when moving from a safety deposit storage area to a customer service area. Preferably also, the personnel progressing the box also carries a tag so that their identity is determined. This allows inventory tracking in both directions and is particularly advantageous in circumstances where the box is moved regularly or the envelopes are often moved between boxes.

To maximise the reliability of the operation of closely stacked or spaced tags, such as those used in Figure 12, the tags operate in either of two current states. At any one time, a small proportion of the tags are in a normal current state where the tags are responsive to all interrogator commands, and the remainder of the tags are in a low current state where those tags are not fully functional. Importantly, the majority of the tags are in the low current state and their current consumption is reduced to reduce the current drawn from their antenna coils. Reducing the current drawn from the antenna coils reduces the average coupling between the closely located tag antennae. That is, this arrangement provides a good average spatial diversity between the normal current tags.

In the Figure 12 embodiment, where the tags must operate when within a few millimetres of each other, the probability of an individual tag being in the normal state 1/16.

In some embodiments the limiting factor is not the time taken for the tags to be interrogated. That is, in use, the tags are disposed within the interrogation field for longer than it takes to interrogate them all. In these embodiments it is possible to further reduce the probability of the tags being in the normal state and thereby achieve a spacing that is less than that of the Figure 12 embodiment.

The tags randomly select their current state autonomously, where the tags randomly choose a current state, receive commands and data and/or transmit replies and then randomly choose a new current state. In alternative embodiments, however, the interrogation signals from the interrogator are used to direct tags to select a new current state and the tags randomly choose the current state they select. These interrogation signals in some embodiments take the form of short breaks in the interrogation field. Examples of such breaks include a single break and a coded break where the sequence of breaks directs

the tags to perform a different type of current state selection. In further alternative embodiments, other forms of modulation of the interrogation field is used to direct tags in their selection of current state. Examples of such modulations include amplitude, phase and frequency modulation.

Random selection of the current state provides the spatial diversity of normal current tags. In the Figure 12 embodiment, a weighted algorithm is used to ensure that only a small percentage of tags, in this case less than 10%, select the normal current state. The algorithm is structured so that within a fixed number of current state selections a tag will be guaranteed to have been in the normal current state at least once.

Alternatively tags select a current state dependant upon a fixed number such as a unique serial number or the contents of their memory. If each tag has a unique number, as is the case for the described preferred embodiments, then a portion of that number is used by the tag to choose a current state. More particularly, in the Figure 12 embodiment, a 4-bit mask is applied to 4 bits of the unique number providing a 4 bit value that is used by the tag to select when it enters the normal current state. In this case, the value of the 4 bits represents the number of interrogator breaks or commands received before the tag enters the normal current state. The mask is moved along the unique number after the tag exits the normal state. This ensures that the tag keeps changing when it chooses to enter the normal current state. Eventually the mask must always move to a part of each tags' number that is different from all adjacent tags. In this way adjacent tags with similar numbers are prevented from always moving to the normal current state at the same time.

Another application is illustrated in the Figure 14, where tag 1 is shown disposed between two cut-away layers 21 and 22 of a laminated envelope 23. While tag 1 is shown in the Figure as protruding from between the layers, that is for the purposes of illustration only. It will be appreciated that, in use, tag 1 is completely enclosed by the layers.

Envelope 23 is applicable for postal and courier use, amongst others. As tag 1 is operable, even when in close proximity to a number of like tags, it is possible to reliably interrogate the tags.

For postal envelopes, the user is able to pre-program the tag to include address and content information to facilitate sorting of the envelope in the postal system. Moreover, the tag is, in some embodiments, pre-programmed with an encrypted message for the intended recipient. For courier envelopes, the courier pre-programs the tag to include data about the intended recipient, the contents of the envelope, the priority of the required delivery, and other data.

Although the tag is shown sandwiched between two layers of the envelope, in other embodiments it is attached by other means. For example, one embodiment makes use of a plastics pocket formed on the exterior layer of the envelope for selectively receiving the tag. In another embodiment, the tag is simply placed within the envelope with the other contents. Other alternatives would also be apparent to the skilled addressee in light of the teaching herein.

The interrogator is either a fixed installation device or, in other embodiments, a handheld device. In any event, the interrogator provides an interrogation signal – in the form of an RF field – that is detected by and selectively responded to by the or each tag in the field.

The RFID tags of the preferred embodiments provide a re-usable resource, as the tags are re-programmable. Moreover, unlike bar codes, they will not be so easily disabled through physically rough handling.

In another embodiment of the invention, a tag is disposed within the packaging for a saleable item. Following the placement of the item into the packaging the tag is programmed to include data indicative of the quantity or quality of the contents. This allows ease of distribution and inventory control from the point of packaging to the ultimate point of sale. This embodiment is particularly advantageous when applied to packaging for computer software. However, it is also applicable to other items such as compact disc's, toys, integrated circuits, books and any other goods that are packed closely together for storage or transportation.

The use of the tags of the preferred embodiments with articles, in addition to allowing ease of inventory control, facilitates the automated sorting of those articles. This is well illustrated in the context of the jewel handling system and also in the context of mail handling systems – where each piece of mail includes a tag.

In more complex embodiments, use is made of a number of tags with a single article. In the case of an envelope for courier use, one of the tags contains data readable only by the courier organisation, while the other tag includes data only readable by the sender and recipient of the envelope.

The preferred embodiments of the invention have been developed for identifying passive tags that are attached to closely stacked objects to be identified by those respective tags. A typical application is the identification of RFID tags attached to bundles of letters where the tag data is used to control the automatic sorting of each letter. However, the invention is not limited to this particular field of use. For example, various aspects of the invention are applicable to systems used for identification or inventory management of high value items such as shoe uppers or shoe soles and diamonds or jewellery.

In the prior art systems, tags are used to identify items such as baggage or persons and are designed to operate at ranges of up to 1 metre. The application of such technology is limited to circumstances where tags are well spaced and there is negligible mutual coupling between the antenna coils of the respective tags. The preferred embodiments of the invention, however, are able to address this limitation and can be stacked and continue to reliably operate.

This allows the preferred embodiment to be applied advantageously to new uses such as those applications in manufacturing where items are closely packed in stacks for storage and transport efficiency. Identification, stock control and inventory management of these items need no longer occur manually for each individual item. A tag of the preferred embodiments, that will operate when stacked, allows these processes to be done in bulk and automatically without the need for manual intervention.

The above description illustrates that the preferred embodiments of the invention provide many advantages over the prior art systems.

The invention has been described with reference to a number of specific examples, and it will be appreciated that by those skilled in the art that the invention can be embodied in many other forms.

DATED this 22[nd] of August 2002

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Fellow Institute of Patent and Trade Mark Attorneys of Australia

of BALDWIN SHELSTON WATERS

ABSTRACT

A radio frequency identification ("RFID") device or tag (1). The tag (1) includes coil antenna (3) for receiving an interrogation signal. A transceiver, in the form of an integrated circuit (4), is connected to the coil (3) and is responsive to the interrogation signal. Circuit (4) selectively draws current from the coil and toggles between a first mode and a second mode, wherein the current drawn from the coil (3) by circuit (4) during the first mode is greater than the current drawn during the second mode. The second mode is on average about 16 times longer in duration than the first mode. That is, the time that circuit (4) is drawing a high current – and thereby being at risk of mutually coupling tag (1) with an adjacent tag – is about 1/16 of the time.

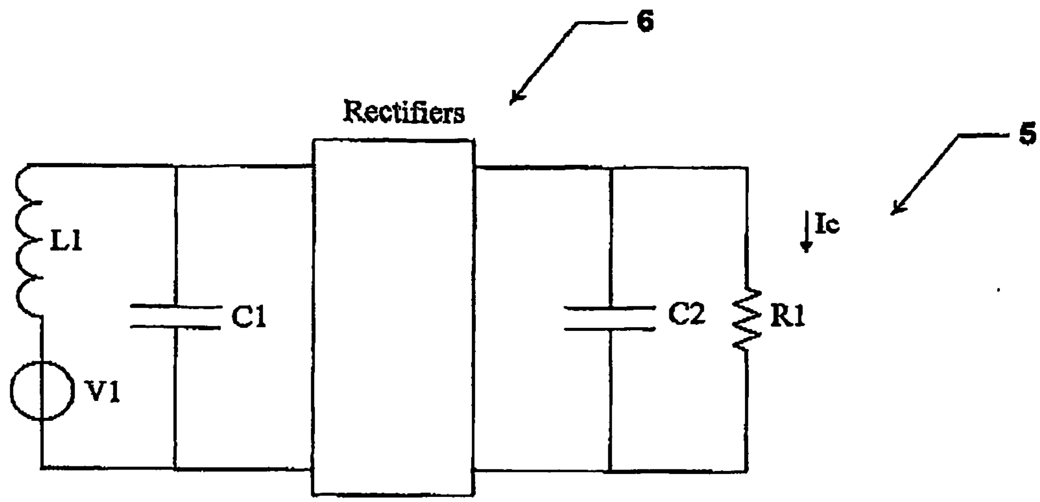


Figure 1

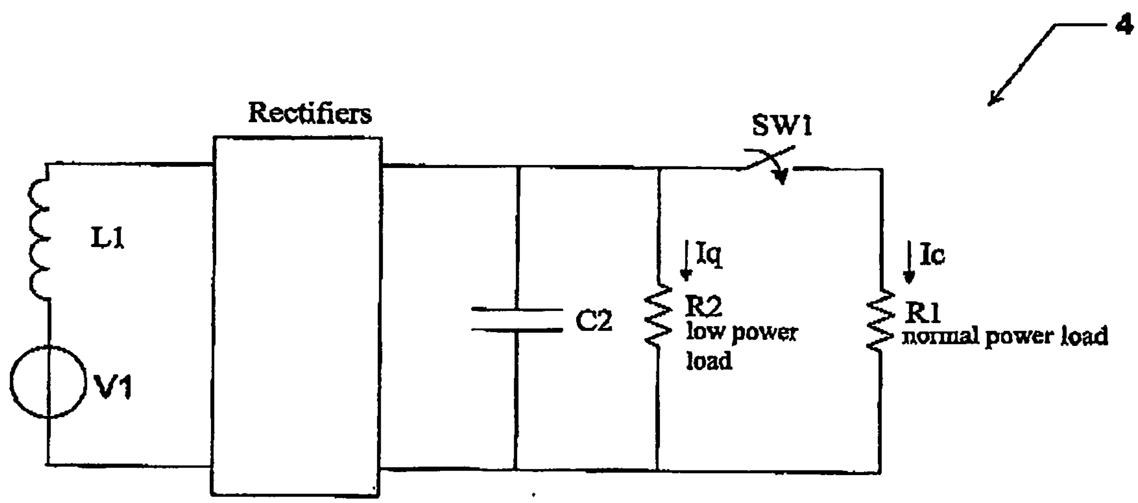


Figure 2

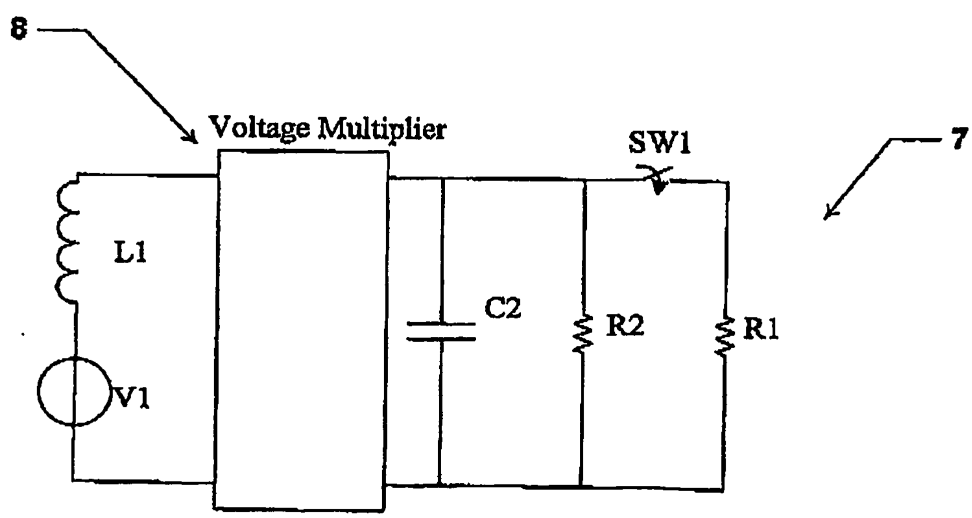


Figure 3

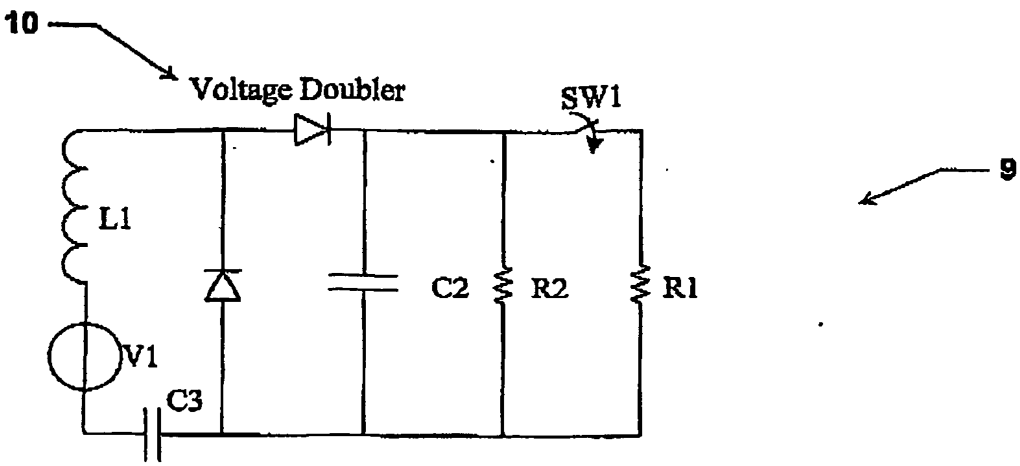


Figure 4

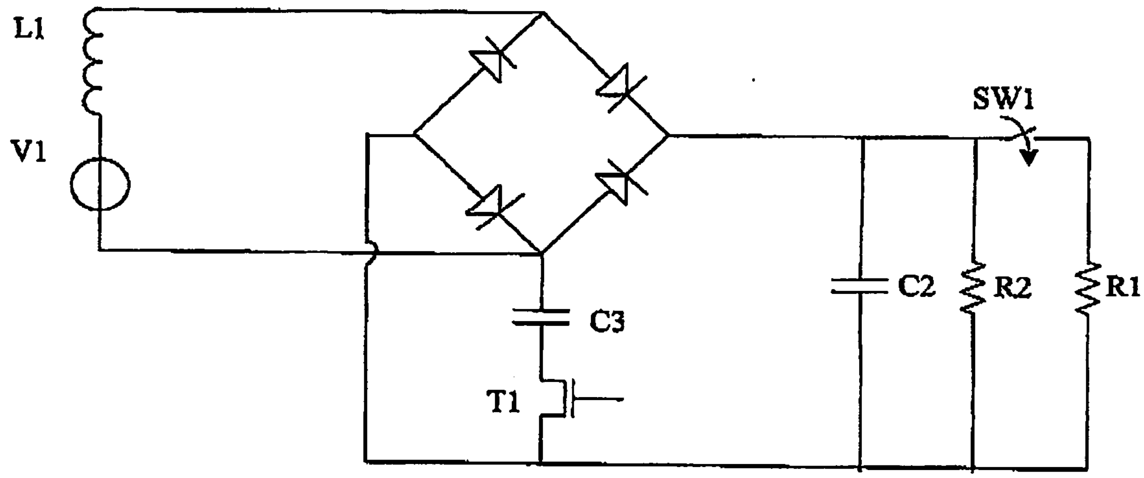


Figure 5

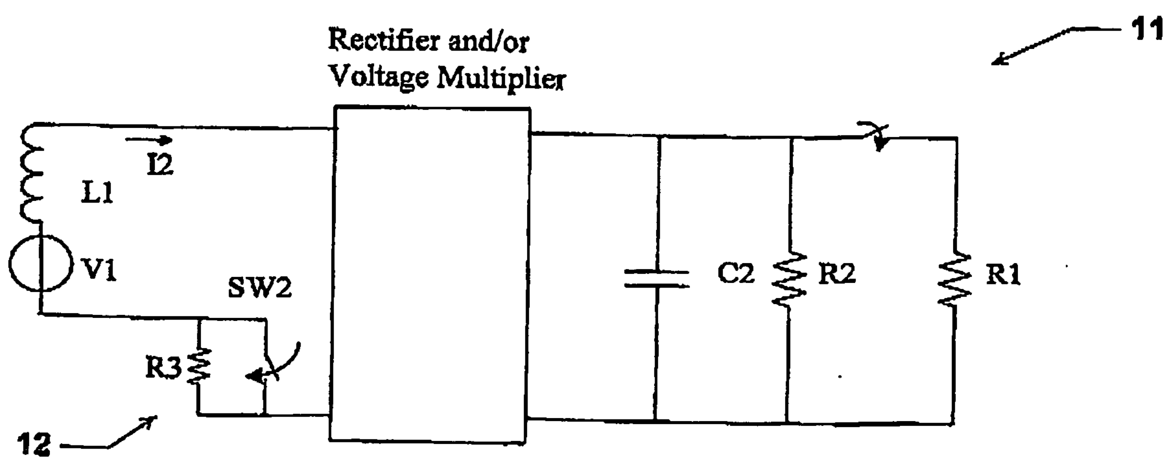


Figure 6

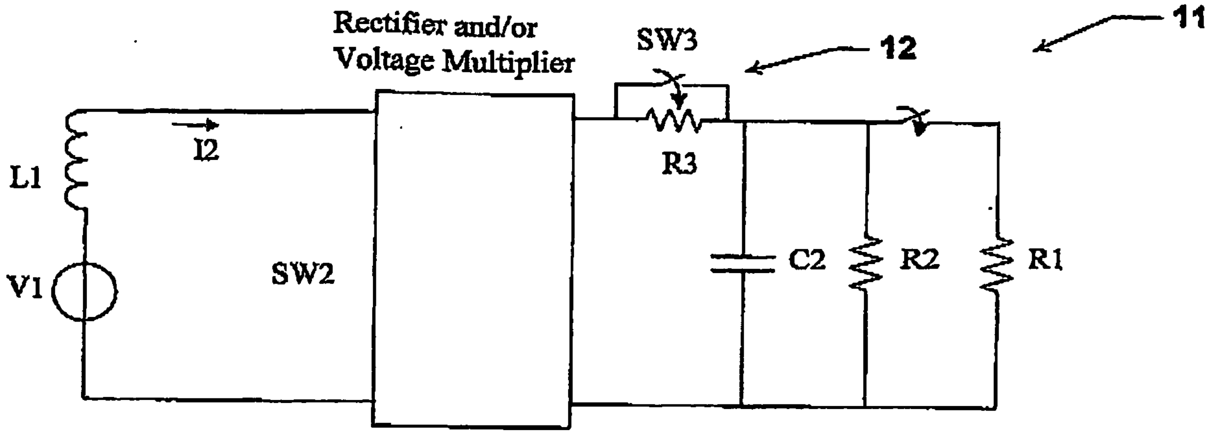


Figure 7

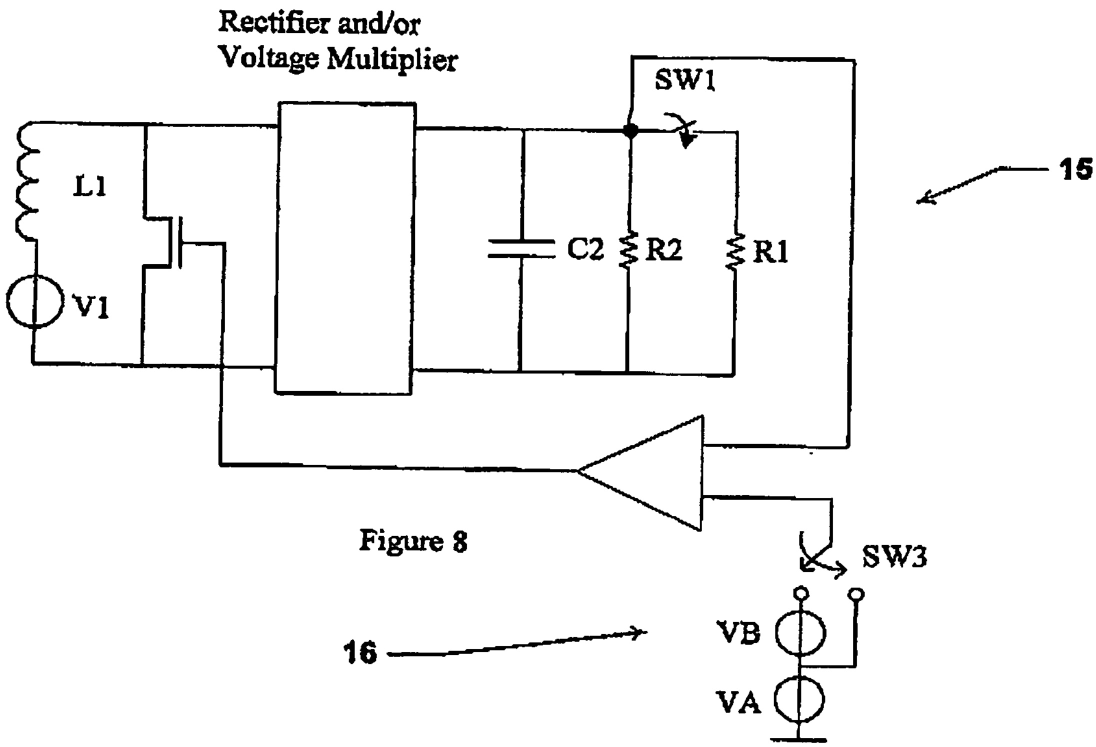


Figure 8

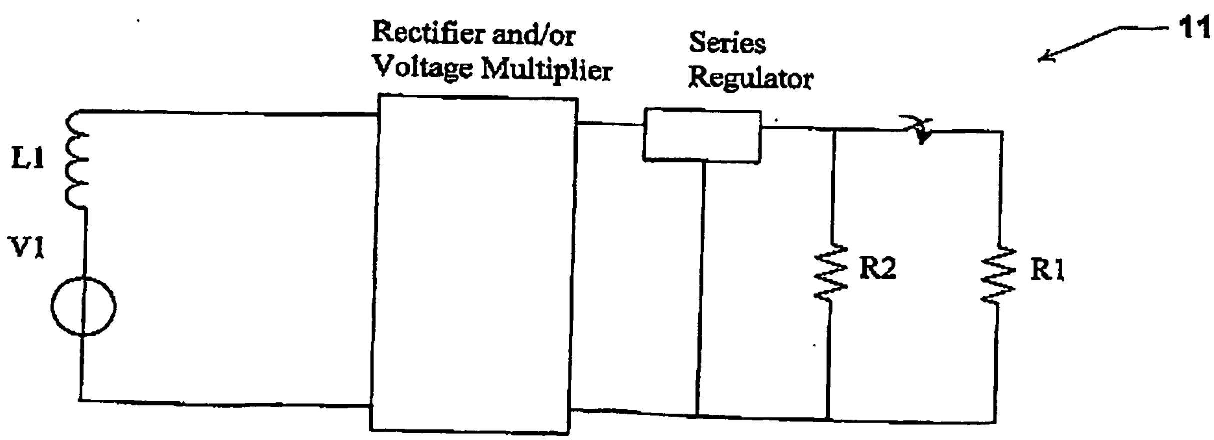


Figure 9

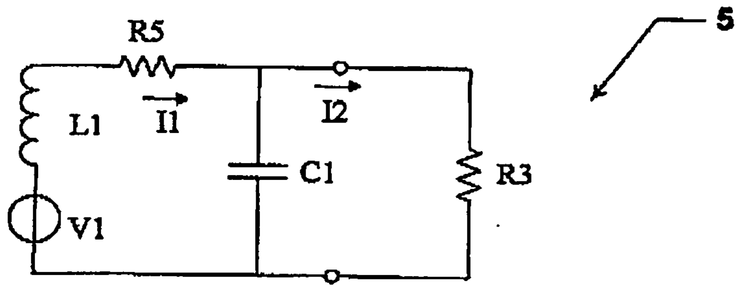
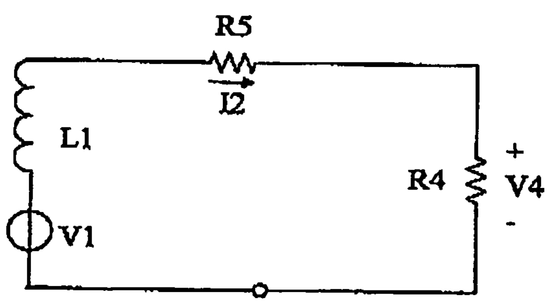


Figure 10



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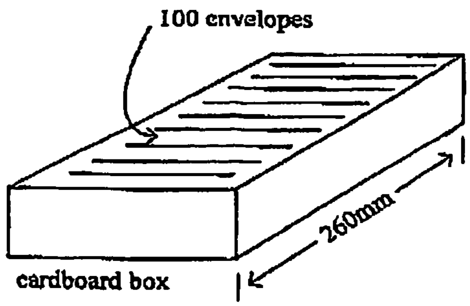

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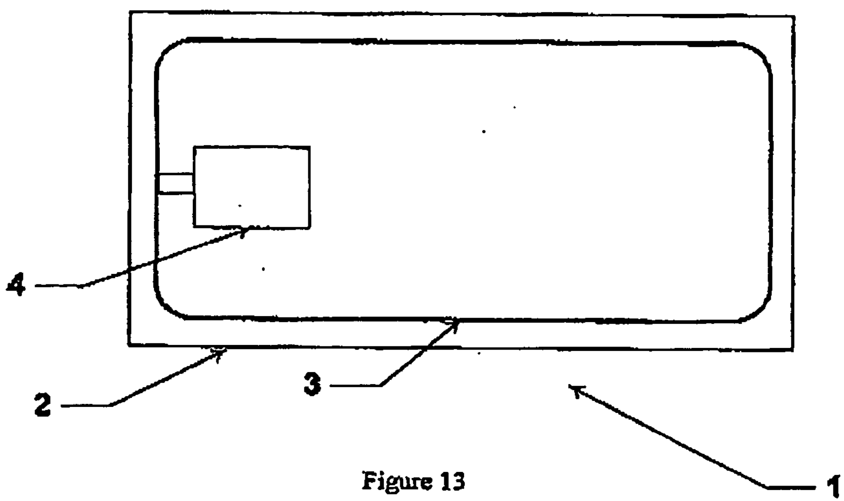

Figure 13

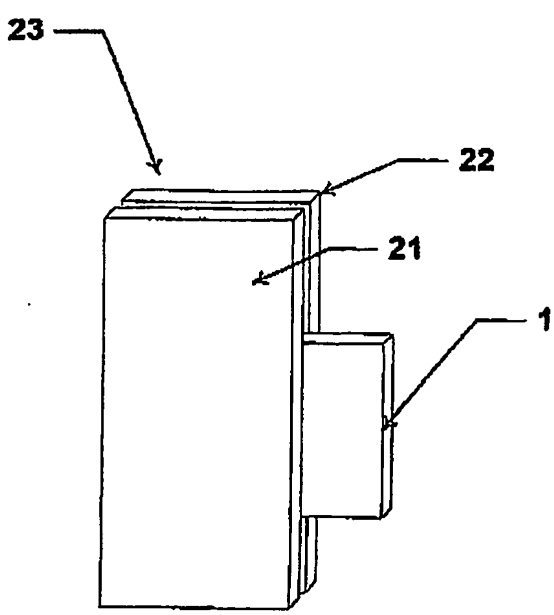

Figure 14

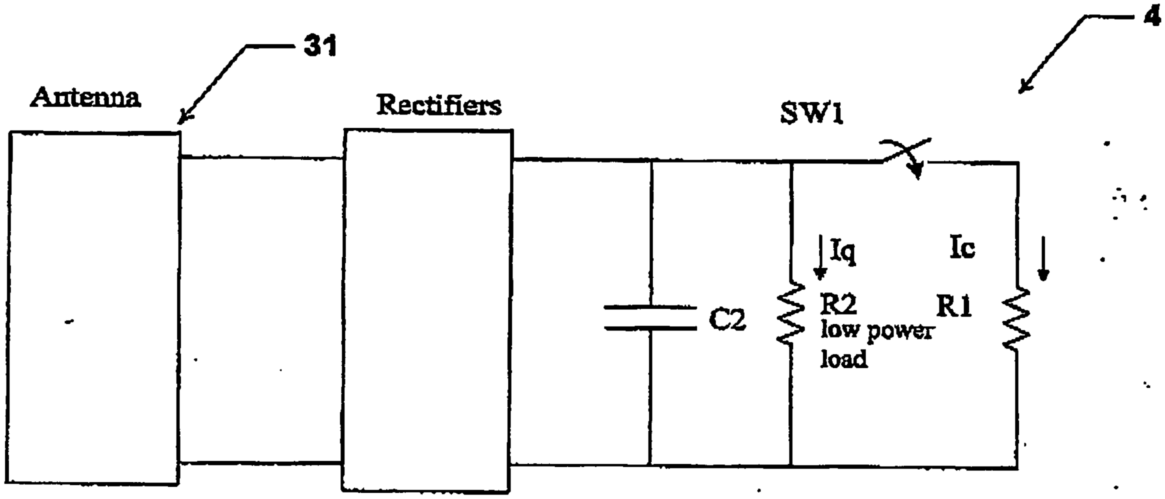

Figure 15

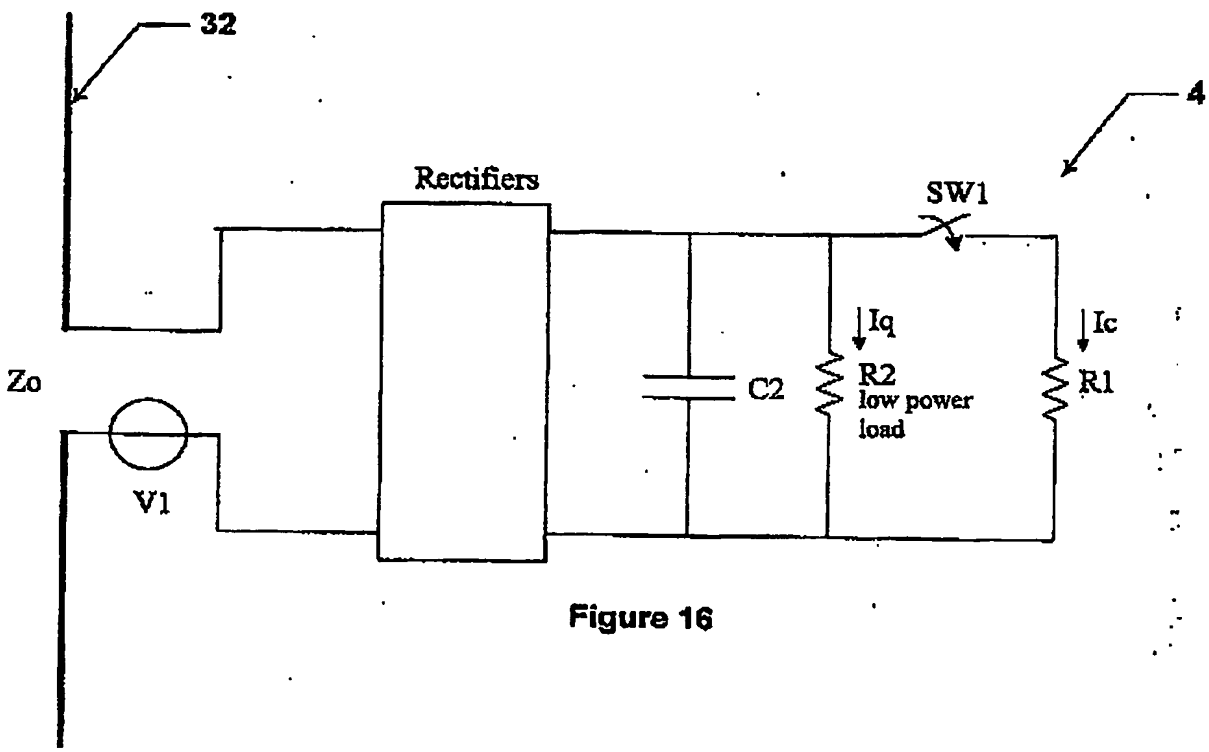

Figure 16

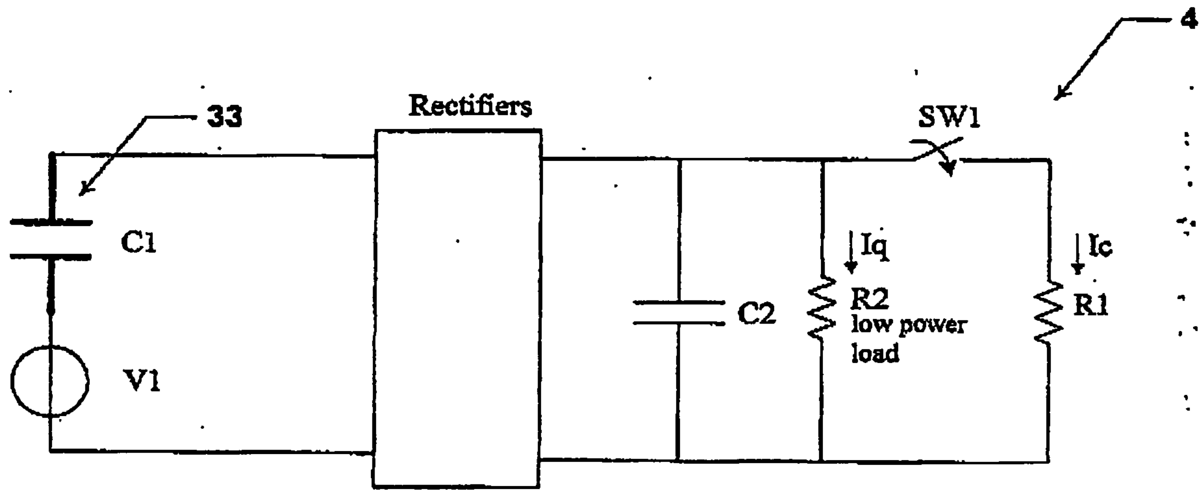

Figure 17